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COLLAPSIBLE DUCT

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BACKGROUND OF THE INVENTION

3 The present invention relates to ducts for
4 containing cables, such as optical cables, and to methods
5 for mounting such ducts in an enclosure or conduit.

6 In the telecommunications industry it is common
7 practice to string cable through a duct, which has
8 previously been placed in an outer conduit. The cable
9 may be electrical, optical or any other type. In recent
10 years, data transmission through optical cable has vastly
11 expanded. As a result, there has been a great increase
12 in demand for cable to carry the digital data. Existing
13 conduits, both above and below ground, have been utilized
14 for new ducts and cables. The old contents of the
15 conduit, usually electrical cable, are removed and ducts
16 are installed, through which optical cables are
17 subsequently placed. U.S. Patents 5,027,864 and
18 4,565,351, the contents of which are hereby incorporated
19 by reference, are examples of this.

20 Existing conduits have a limited amount of interior
21 space. Further, the conduits may extend along a tortuous
22 path characterized by multiple bends and adjacent length
23 portions extending in non-planar directions. They are
24 usually circular in cross section and often are buried or
25 otherwise not readily accessible. The ducts, which are
26 placed in the conduits, usually have relatively rigid,
27 circular cross-sections but are flexible along their
28 length. Consequently, multiple ducts are difficult, if
29 not impossible, to insert within conduits in some cases.

30 Using circular duct in a circular conduit is an
31 inefficient utilization of space. That is, there is a
32 considerable amount of wasted space between the circular
33 ducts. For example, a conduit with a 4" internal

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1 diameter would hold only three ducts with a nominal 1 $\frac{1}{4}$ "
2 internal diameter. This inefficient use of the conduit
3 interior space or cross-sectional area corresponds with a
4 low packing efficiency.

5 In further efforts to achieve cable installation
6 efficiencies, consideration has been given to the
7 mounting or stringing of cable within existing utility
8 service lines such as gas or water lines. Such an
9 installation technique would provide a low-cost cable
10 pathway to a home or business. However, such utility
11 service lines are typically not oversized for the volume
12 of water or gas that they are intended to deliver and may
13 only range in diameter from one to several inches.
14 Accordingly, even though the cable conduit may be small
15 in diameter, it would still occupy a significant volume
16 and cross-sectional area of the service line and tend to
17 interfere with the utility delivery.

SUMMARY OF THE INVENTION

19 In accordance with the present invention, ducts
20 having a variable cross-sectional configuration provide
21 pathways for cables. The variable cross-sectional
22 configuration of the duct facilitates mounting of the
23 duct in an enclosure or conduit and also enables
24 increased numbers of ducts to be mounted in a given size
25 conduit. The cable may be inserted in the duct prior to
26 or after the duct is mounted within the enclosure or
27 conduit.

28 The cross-sectional configuration of the duct may be
29 varied between an extended condition of greater cross-
30 sectional area and a contracted condition of lesser
31 cross-sectional area. Typically, the duct is normally in
32 the contracted condition and is manipulated to the
33 extended condition as by fluid pressure.

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1 The facilitating of duct mounting in a conduit
2 relates to the reduced cross-sectional area of the duct
3 in the contracted condition and also to the reduced
4 cross-sectional profile of the contracted duct as well as
5 the increased duct flexibility or conformability provided
6 by the collapsible duct wall. That is, the varied
7 degrees of duct bending required as the duct is moved
8 along a tortuous path are more readily accommodated by
9 the variable cross-sectional configuration and
10 collapsible wall of the duct.

11 This invention includes a method of installing a
12 cable in an inner pathway or duct. The duct has a
13 collapsible wall which is movable between an extended
14 condition and a contracted condition. The extended
15 condition has a greater cross sectional area than the
16 contracted condition. The duct is inserted, in the
17 contracted condition, into an outer conduit. The duct is
18 moved to the extended condition and the cable is inserted
19 into the duct. The duct is subsequently moved to the
20 contracted condition. The duct may also be used without
21 an outer conduit.

22 This invention further includes a duct providing a
23 pathway for a cable. The duct includes a collapsible
24 wall movable between an extended condition and a
25 contracted condition wherein the extended condition has a
26 greater cross-sectional area than the contracted
27 position. When the duct is in the extended condition it
28 is suitable to have a cable passed through it
29 longitudinally. When the duct is in the contracted
30 position it may be placed in a conduit in greater numbers
31 than an equivalent size of a non-collapsible duct.

32 This invention greatly enhances the efficiency of
33 existing conduits. In this invention the ducts are made
34 of a collapsible or flexible material. While the ducts

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1 are sturdy enough to remain intact when cable is passed
2 through them, the ducts have a normally contracted
3 configuration of reduced cross-sectional area and, for
4 example, they may collapse under their own weight. That
5 is, the ducts flatten themselves unless there is a force
6 to open them, such as air pressure. In this invention,
7 the flattened ducts are pulled or pushed, in a flattened
8 state, through a conduit. In a 4" internal diameter
9 conduit there would be room for seven nominal 1 $\frac{1}{4}$ " ID
10 flattened ducts. This is over twice the number of rigid
11 ducts of the same size.

12 When it is desired to place a cable in the duct, the
13 duct is simply inflated. A source of air pressure,
14 usually an air compressor, is connected to one end of the
15 duct. The air pressure causes the duct to inflate to an
16 expanded oval or circular cross section sufficiently
17 large to permit a cable to pass through it. After the
18 cable is inserted, that duct is deflated and another one
19 is inflated. This process continues until all of the
20 ducts have had a cable placed in them. The increase in
21 capacity and efficiencies from this invention are
22 obvious.

23 The size constraints that have heretofore inhibited
24 the mounting of ducts in existing service lines or other
25 pipelines are significantly lessened, if not overcome, by
26 the collapsible ducts of the invention. That is, a
27 greater number of cables may be contained in a smaller
28 size duct and the cross-sectional area of the installed
29 duct is itself reduced by collapsing the duct about the
30 cables following installation. In this manner, a greater
31 number of cables may be installed in a service line or
32 pipeline with a minimal amount of flow reduction.

DESCRIPTION OF THE DRAWINGS

Fig. 1 is a side elevation, partly cut away, of the duct of this invention.

Fig.2 is a front view of the duct of this invention.

Fig.3 is perspective view of the collapsible ducts being pulled through a conduit with parts broken away for clarity of illustration.

Fig.4 is front elevation of three ducts joined along their lengths and having ribs.

Fig.5 is a side elevational view of the interior of one of the ducts of Fig. 4.

Fig.6 is an elevational view similar to Fig. 5 of a duct in accordance with another embodiment.

Fig. 7 is a perspective view of an alternate embodiment of this invention, including a suspension member.

Fig. 8 is a perspective view of an alternate embodiment of this invention having longitudinal and circumferential grooves.

Fig 9 is a perspective view illustrating collapsible duct in a coiled conduit.

Fig. 10 is an elevational view, partly in section, showing another embodiment wherein a duct in accordance with the invention is mounted within a utility service line.

Fig. 11 is a sectional view, on an enlarged scale, taken along the line 11-11 in Fig. 10.

DETAILED DESCRIPTION OF THE DRAWINGS

As best seen in Figs. 1-3, this invention includes a duct 10 or series of ducts 10a-10g. Each duct 10 forms a pathway 14. The duct 10 has a collapsible or flexible wall 16 which has three layers: an inner layer 18, an outer layer 20 and a reinforcement layer 22 between them.

1 The inner layer 18 is made of a low friction
2 abrasion resistant material that is thin and flexible.
3 Materials that meet these criteria to one degree or
4 another are polyolefins (polyethythylene, thermoplastic
5 elastomers, polypropylene), polyester
6 (polyethyleneterephthalate, polybutyleneterephthalate),
7 polyamide (nylons), polyvinylchloride (PVC),
8 polyvinylidene fluoride, polytetrafluoroethylene,
9 acrylonitrile-butadiene-styrene, styrene-acrylonitrile,
10 poly-sulfones and others known to one skilled in this
11 art.

12 The outer layer 20 is made of a material that is
13 durable and flexible. Known materials include
14 flexibilized PVC's, urethane, thermoplastic elastomers,
15 and silicone or vulcanized rubber compounds.

16 The reinforcement layer 22 must also be strong and
17 flexible. Friction however, is not a concern. It may be
18 made of a woven or non-woven material of organic, glass
19 or metal fiber or bundles of same. Also, a slit-metal
20 material of sufficient flexibility and resiliency may be
21 used.

22 The reinforcement layer may be characterized by a
23 bias ply or helical wrap arrangement to achieve the
24 desired hoop strength and duct burst strength. The
25 extrusion of the duct layers may provide longitudinal
26 molecular orientation of the layer material and increased
27 longitudinal tensile strength. However, longitudinal
28 members may be used for added tensile strength. It
29 should be understood that more or less layers may be
30 used.

31 The duct 10 has a normally collapsed configuration
32 of reduced cross-sectional area. The duct may be
33 collapsible of its own weight. In the collapsed or
34 contracted condition, the aspect ratio of the major duct

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1 dimension to the minor duct dimension (e.g. the major and
2 minor axes of an ellipse or oval) may range from about
3 1.1:1 to about 25:1. Often, oval shape ratios range from
4 about 5:1 to about 10:1.

5 The layers 18, 20 and 22 may be provided of the
6 materials described herein and formed with various
7 thicknesses selected in accordance with strength, wear
8 and other design parameters while achieving the required
9 flexibility or collapsibility to enable the duct to be
10 operated between its extended and contracted conditions.
11 The layer thickness may be varied to allow for variations
12 in the stiffness of different construction materials.
13 For example, layers formed of polyamides may be thinner
14 than layers formed of polyolefins. Illustrative
15 thicknesses for inner and outer layers formed of
16 polyethylene may range from 0.01 to 0.2 inches. The
17 thickness of the reinforcement layer 22 will typically be
18 less than that of the outer layer and will range from
19 about 0.02 to about 0.2 inches.

20 The duct 10 has a generally tubular shape, and the
21 wall 16 is of a uniform construction and closed about the
22 longitudinal axis of the duct. As described above, the
23 construction of the wall 16 is collapsible about its
24 entire periphery to provide increased applicability of
25 the duct to various enclosures or conduits of restricted
26 interior space. However, the wall 16 may include a
27 noncollapsible portion joined to a collapsible portion to
28 provide increased duct rigidity required in certain
29 conduit applications characterized by less structural
30 support.

31 As shown in Fig. 3, the ducts 10a-g may be pulled
32 though a conduit 24 by chains 26a-g connected to
33 associated ducts by plugs 30 mounted within the open end
34 of each duct. A ring 27 connects the chains 26a-g to a

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1 hook 28 extending from a cable 31 which is often
2 connected to a winch (not shown).

3 It should be appreciated that the ducts 10 are in
4 their normally collapsed or contracted condition rearward
5 of the plugs 30. For example, rearward of the breakline
6 "A" extending through the lead group of ducts 10a, 10b
7 and 10c, the downstream remaining portions of these ducts
8 are in their normally collapsed configuration and pass
9 alongside the expanded portions of the ducts 10d, 10e,
10 10f and 10g. The conduit 24 has a cross-sectional area
11 sufficient to accommodate at least three collapsed ducts
12 in juxtaposition with four extended ducts. The chains
13 are different lengths in order to stagger the leading
14 edges of the ducts 10a-g. Since the plugs 30 open the
15 ducts to their full diameter, they may not all be pulled
16 through the conduit 24 with the leading edges aligned and
17 extending in the same plane. It is also possible to pull
18 the ducts sequentially through the conduit in separate
19 groups. The devices for pulling or pushing ducts are
20 many, varied and well known in the art.

21 In the present invention, the ducts 10a-g are in a
22 collapsed or contracted position rearward of the plugs 30
23 as they are drawn through the conduit 24. In the
24 collapsed or contracted position, many more ducts can be
25 installed in a conduit. For example, seven 1 $\frac{1}{4}$ " collapsed
26 ducts could be placed in a 4" ID conduit. Whereas, only
27 3 such ducts could be placed in a 4" conduit if the ducts
28 had the full 1 $\frac{1}{4}$ " circular cross-section.

29 In this invention, the duct 10 has an oval cross-
30 section when it is in its normal or contracted condition
31 as best seen in Fig. 2. It is in this contracted state
32 when the ducts are placed in the conduit 24. After the
33 ducts 10a-g are in place, they are expanded and cables
34 are inserted into the ducts.

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1 In order to move or operate the ducts to their
2 extended state, air pressure is applied to one end of the
3 duct. That is, air is forced into the entire length of
4 one (or more) of the ducts to inflate or displace it to
5 its extended condition. In its extended condition, a
6 duct will have an expanded oval or circular cross-
7 section. While in this condition, a cable is placed in
8 the duct by either pushing or pulling it. After the
9 cable is in place, the duct is returned to its contracted
10 condition by stopping the air flow through it. This
11 process is repeated on each of the ducts either one at a
12 time or perhaps more until all of the ducts have a cable
13 in them. This invention also contemplates other ways to
14 expand the duct, such a liquid pressure, a low pressure
15 on the outside of the duct and any other way to put the
16 duct in its extended condition.

17 Fig. 4 illustrates an enhancement of the present
18 invention. As shown in Fig. 4, the ducts 34a, 34b and
19 34c, if desired, may have internal ribs 40 and/or
20 external ribs 42. The external ribs 42 have the purpose
21 of reducing the frictional forces as the ducts 34a-c are
22 placed in a conduit. The internal ribs 40 similarly
23 reduce the frictional forces as cables 44a-44c are placed
24 in the ducts 34a-34c. The ribs 40 and 42 have a spiral
25 configuration. The spiral shape and function are
26 described in greater detail in patent 5,087,153,
27 incorporated earlier.

28 The ducts 34a-34c are shown in Fig. 4 in an extended
29 position for illustration purposes. Normally, they would
30 be in a contracted position. The ducts 34a-34c are
31 secured together along their lengths at joints or
32 connections 36 and 38. The connections may extend along
33 the entire lengths of the ducts or be located at spaced
34 intervals. The connections may be made during the

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1 molding process, but can be made in any way known in the
2 art, such as heating, fusing, or adhesives. Also, the
3 ducts 34a-34c can be tied together using plastic banding,
4 for example. The connections 36 and 38 prevent or reduce
5 the twisting of the ducts relative to each other as they
6 are strung through a conduit.

7 Fig. 5 illustrates an oscillating arrangement of the
8 internal ribs 40. That is, the ribs 40 extend along the
9 interior surface of the duct 34 in a longitudinally
10 directed repeating wave pattern, e.g., a sine wave
11 pattern. In the wave pattern, the ribs extend in
12 alternate circumferential directions as illustrated in
13 Fig. 5. Straight or longitudinal ribs 46 are shown in
14 Fig. 6. The benefits of these ribs are mentioned above
15 and described further in Patent 5,087,153, which is
16 incorporated by reference.

17 Another embodiment of a suspended duct 47 is
18 illustrated in Fig.7 wherein a strand 48 supports a
19 conduit 50 into which two ducts 52 and 54 have been
20 placed. As described earlier, the ducts 52 and 54 are
21 collapsible or flexible. The conduit 50 is also
22 flexible. The ducts 52, 54 and conduit 50 may be formed
23 of the materials described above.

24 In this embodiment, the conduit 50 is molded to
25 enclose the strand 48. The ducts 52 and 54 may be
26 molded with the conduit 50 or placed therein. The strand
27 48 is strong enough to support the entire structure
28 between poles or other supports above the ground. A
29 cable 56 is placed in the duct 52 in the same way as
30 described above, that is, by inflating the duct 52 into
31 an extended condition and then letting the duct 52 return
32 its contracted position after the cable is placed
33 therein.

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1 Fig. 8 shows a corrugated duct 60 having an inner
2 layer 62, a reinforcement layer 64 and an outer layer 66.
3 The layers 62, 64 and 66 may be formed of the same
4 materials as described above with respect to such layers.
5 In this embodiment, the outer layer 66 has longitudinal
6 grooves 68 and circumferential grooves 70 formed within
7 the layer thickness.

8 The grooves 68 and 70 have a depth equal to about 25
9 to about 75% of the thickness of the layer 66, but other
10 groove depths may be used. Increased groove depth
11 provides greater duct flexibility.

12 The width of the grooves 68 and 70 is typically much
13 less than the diameter of the duct and, often, may be an
14 order of magnitude less than the diameter. For example,
15 a duct having a 4" ID may have groove widths ranging from
16 about 1/16" to about 5/8" or greater. Also, the grooves
17 may not be of equal or uniform widths. Increasing groove
18 widths will increase the duct flexibility.

19 The groove spacing or frequency may also be selected
20 to achieve the desired degree of flexibility, with
21 decreasing spacing yielding increasing flexibility.
22 Typical spacing of longitudinal grooves may range from 30
23 to 60 degrees or more. Axial spacing of circumferential
24 grooves may range from a fraction of the duct diameter to
25 several times the diameter.

26 In all cases, it should be appreciated that the
27 size, location and frequency of the grooves may be
28 selected to optimize or fine tune the desired flexibility
29 in a given material system. Similarly, it enables
30 increased freedom of material selection and cost
31 advantages since the corresponding restrictions in the
32 resulting flexibility or collapsibility are reduced.

33 This grooved duct is particularly useful in
34 applications requiring a high degree of duct flexibility

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1 in multiple planes or directions. Also, this duct
2 construction is especially useful in mounting
3 arrangements wherein it is attached to members that may
4 expand and contract, causing the duct to do the same
5 thing. Of course, the duct would have to expand and
6 contract without breaking. One such application would be
7 attached to a bridge.

8 It is possible to place collapsible ducts 10a-g in a
9 conduit 72 during production as shown in Fig. 9. In this
10 embodiment the conduit 72 is corrugated and encloses the
11 ducts 10a-g, shown in their contracted condition. The
12 conduit 72 could be produced and placed on a coil. At
13 the installation site the enclosed ducts 10 would be
14 simply laid with the conduit 72. The cables would be
15 installed as described earlier.

16 The manufacture of the assembled conduit 72 and
17 ducts 10 as shown in Fig. 9, enables the ducts to be
18 introduced into the conduit under controlled
19 manufacturing conditions. Accordingly, the installation
20 in a tortuous job site configuration is facilitated, if
21 not made possible, by the preassembly of the conduit and
22 ducts.

23 Referring to Figs. 10 and 11, a service line 74 for
24 providing a utility service such as natural gas or water
25 is shown. The service line 74 is of conventional
26 construction and may be a rigid or flexible pipeline
27 formed of a suitable material, for example, plastic. As
28 shown in Fig. 10, a duct 76 is mounted within a portion
29 of the service line 74.

30 The duct 76 is similar to the ducts or conduits 24,
31 47, 60 and 72 described above. Accordingly, the duct 76
32 has a collapsible or flexible wall 78 of multilayer
33 construction. At least the outermost layer of the wall
34 78 provides a fluid tight seal and is substantially inert

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1 to the water or gas utility being supplied in the line
2 74. In this manner, the gas or water is separated and
3 isolated from cables 80 contained within the duct 76.

4 The duct 76 is introduced into the service line 74
5 at an entrance location 82 which may, for example, be
6 near the utility street supply line. The duct 76 is
7 withdrawn from the service line 74 at an exit location 84
8 just before the service line goes into the meter riser.
9 In this manner, the service line 74 provides a low-cost
10 pathway to the home or business.

11 At the entrance location 82, an opening 86 in the
12 wall of the service line 74 communicates with a surface
13 mount clamp 88 arranged to receive the duct 76 with a
14 fluid tight seal. To that end, the clamp 88 includes a
15 nozzle 90 through which the duct 76 passes as it is
16 introduced into the service line 74. The nozzle 90
17 includes a ferrule seal 92 which may be sealed against
18 the duct 76 by tightening a locking nut connector 94.
19 The ferrule seal 92 encircles the duct 76 and is
20 sufficiently compressed upon tightening of the connector
21 94 to form a continuous seal along the outer surface of
22 the duct 76 when the latter is in the contracted
23 condition.

24 At the exit location 84, an opening (not shown)
25 similar to the opening 86 is provided in the wall of the
26 service line 74 together with a second surface mount
27 clamp 96 having a locking nut connector 98 operable to
28 cause a second ferrule seal 92 (not shown) to engage the
29 duct 76 with a fluid tight seal as the duct exits the
30 service line 74.

31 In an illustrative example, the service line 74
32 comprises a one inch diameter plastic natural gas supply
33 line to a residential home. The duct 76 has a
34 polyurethane outer layer, a 3/8 inch outer diameter in

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1 the extended condition and contains a plurality of fiber-
2 optic cables 80. With the gas service interrupted and
3 the line 74 free of residual gas, the collapsed duct 76
4 is strung through the service line 74 using known
5 techniques. The opposite ends of the duct 74
6 respectively extend from the clamps 88 and 96.

7 In the same manner as described above, the duct 76
8 is expanded and the cables 80 mounted therein. The duct
9 76 is then contracted in order to minimize the duct
10 cross-sectional area and its effect on the service line
11 74. The opposite end portions of the duct 76 are then
12 engaged in fluid tight seals by tightening the locking
13 nut connectors 94 and 98. These seals close the service
14 line, and the gas supply through the line 74 may be
15 resumed.

16 Although particular embodiments of the invention
17 have been described in detail, it is understood that the
18 invention is not limited correspondingly in scope but
19 includes all changes and modifications coming within the
20 spirit and terms of the claims appended hereto.

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